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### Network Configuration

#### 5 THE BACKGROUND OF THE INVENTION AND PRIOR ART

The present invention relates generally to network design. More particularly the invention relates to a method of configuring a resource distribution network according to claim 1, a computer program according to claim 20 and a computer readable medium according to claim 21.

There exist different types of networks through which resources are distributed from a relatively low number feeding points to a relatively large number of exit points. The most typical example of such a network is perhaps the electrical energy supply network, into which electrical energy is entered by one or more energy sources (either directly from a power plant or via a transforming plant) and from which the energy is utilized by clients in the form of factories and households. Water supply- and sewerage networks constitute equivalent examples where water is transported instead of electrical charges. A sewerage network is, of course, different from the water supply network in that the water flow is reversed, i.e. it originates in a relatively large number of client points and ends in a relatively low number of receiving points, for instance represented by purification plants. However, since the resources (i.e. the waste water) here can be said to have a negative value, a positive flow of resources can still be defined as being directed towards the client points. Gas networks and district heating networks represent additional examples of such resource distribution

networks.

Obviously, in the above network examples it is uncritical which client who receives a specific piece of resource. In other types of networks, for instance tele- and data communication networks it is highly important that a specific information stream is directed towards an intended receiver. However, all the mentioned network types have a core of characteristics in common. It is namely always the case that, for each client, there exists a certain minimum amount of resources that should be granted at a particular service level (for instance defined in terms kVA (kilovolt Ampere) and a maximum number of hours of non-operation per year respectively). Consequently, it may indeed be an intricate task to design a wide-extended network which includes a very large number of client points. The problem may be further complicated by the fact that the load generated by each client generally varies over time. Sometimes these variations essentially overlap in time among at least a local majority of clients, whereas during other periods the loads may be more separated in time such that the combined load from a plurality of clients becomes comparatively stable although the individual client loads vary considerably.

Traditionally, the capacity of the types of resource distribution networks discussed above is adapted to a demand from the currently connected clients, and possibly expected future clients. In most cases therefore, the networks grow gradually from a relatively small initial size up to a size which is required by the circumstances. Due to this situation, it is normal practice to apply various ad hoc methods and rules of thumb when designing the networks. Although a resulting network may meet the demand, the design often becomes imperfect with respect to capacity usage or efficiency of investment. Retrospectively, it is generally also very difficult to determine how a given network configured along these lines could be enhanced with respect to the capacity usage and/or the efficiency of investment.

## SUMMARY OF THE INVENTION

It is therefore an object of the present invention to alleviate the problems above and thus offer an improved solution for designing a resource distribution network. It is also an object of the invention to provide a basis for evaluating the efficiency of an already existing resource distribution network.

According to one aspect of the invention these objects are achieved by a method of configuring a resource distribution network in which resources enter via at least one feeding point and exit at a plurality of client points. The proposed method includes three principal steps in which input data is received, the input data is processed and a generated network configuration is presented respectively. A supply node list is received via a first data input means. The supply node list contains a first set of coordinate data which for each of the at least one feeding point designates a geographical position and a respective amount of resources fed into the network. Similarly, a user node list is received via a second data input means. The user node list contains a second set of coordinate data which for each client point designates a geographical position and a respective estimated average amount of resources exiting at the client point. The supply node list and the user node list are then processed in a digital processor. The processing generates a network configuration where each client point is connected to a particular feeding point, either directly or via at least one other client point. The processing in turn includes the following steps. An initial sectioning step forms a station area around each feeding point, such that a specific client point falls within the station area whose associated feeding point is closest to the client point. If, however, the estimated sum of resources exiting at the client points thus associated to a feeding point exceeds this point's capacity, a sufficiently large fraction of the client points are instead associated to a second closest feeding point. (Naturally, the fraction of client points can only be associated with this second closest feeding point if its capacity so allows.

Otherwise, the fraction of client points will have to be associated to a third closest feeding point, and so on). A grouping step then forms at least one sub-network within each station area according to a network segmenting algorithm. Subsequently, a clustering step associates the client points in each station area with each other, such that two or more client points together form at least one client cluster within the sub-network to which they belong. A connection step finally allocates a respective network station to each client cluster. The client points within each client cluster are connected to their respective network station, and the network stations are in turn connected to the at least one feeding point, such that a particular network station is fed by a certain feeding point. A description of the network configuration is thus attained, which is delivered via a data output means.

An important advantage attained by this method is that a network configuration is accomplished, which is highly beneficial from a geometrical point-of-view. Even though it will seldom be possible to build a physical network exactly according to this configuration, the result constitutes an excellent basis for an actual network design. Furthermore, the generated network configuration may be used when evaluating the properties of an existing network with the specified feeding points and client points.

According to a preferred embodiment of this aspect of the invention, the grouping step includes a district grouping sub-step. Here, each client point in each station area is linked up to the respective station area's feeding point, such that a specific client point is linked to this feeding point either directly or via at least one other client point. The procedure is advantageous because the client points will thereby be connected to the feeding point via relatively short connections. This, in turn, vouches for a short average interconnection length of the connections in the resulting network configuration.

According to another preferred embodiment of this aspect of the invention, the network segmenting algorithm involves the following actions. First, a preliminary sub-network is formed which interconnects all the client points therein with comparatively short connection lengths. After that, a sub-network is divided off from the preliminary sub-network wherever the length of a connection between two client points or between a client point and the feeding point exceeds a threshold distance. Subsequently, a group node list is formed over the client points within each respective sub-network. The group node list specifies for each client point: (1) a radial distance to a geographical position representing a point of balance regarding the geographical positions and estimated average amounts of resources exiting at the client points within the sub-network, and (2) an angular measure, which reflects an angular coordinate between the client point and a client point being located at a next larger and/or a next smaller angular degree in relation to the point of balance. The group node list is arranged in an increasing radius order, such that a first entry represents the client point being located at a smallest radial distance from the point of balance, a second entry represents a client point being located at a second smallest radial distance from the point of balance and so on.

This network segmenting algorithm is desirable, since the resulting sub-networks provide a well-founded basis for the distribution of so-called network stations, i.e. local service stations for a lowest hierarchical level in the network, such that one (or if so demanded more) network station(s) can be assigned to serve each sub-network.

According to another preferred embodiment of this aspect of the invention, the clustering step involves the following actions. A currently last client point in the group node list is assigned to be a first element in a client cluster and is subsequently removed from the group node list. Then, a client point being located geographically closest to the client point that represents the first

element is assigned to the client cluster as a later element. However, the later element is added if and only if at least one boundary condition is fulfilled. Otherwise, the client cluster is defined as full and the later element instead constitutes a first  
 5 element in a new client cluster. The client points in the group node list are continued to be assigned to client clusters accordingly until all the client points in the group node list have been assigned to a client cluster.

10 This clustering procedure is advantageous because it efficiently groups together those client points which are preferably served by one and the same service point, i.e. should be jointly linked to a closest higher hierarchical level in the network.

According to another preferred embodiment of this aspect of the invention, the at least one boundary condition implies that: (a) a  
 15 distance between two client points connected to each other must be less than the threshold distance, and (b) the sum of the estimated average amounts of resources exiting at the client points within a certain client cluster must be less than a threshold amount. These boundary conditions are advantageous  
 20 because thereby safety and quality regulations can be fulfilled simultaneously with various technical limitations in the network nodes being taken into account.

According to another preferred embodiment of this aspect of the invention, the connection step involves the following actions: (i)  
 25 positioning the network station at a geographical position that represents a point of balance regarding the geographical positions and the estimated average amounts of resources exiting at the client points within the client cluster, and (ii) assigning a capacity to this network station which is sufficient  
 30 with respect to the sum of the estimated average amounts of resources exiting at these client points. Naturally, these actions are advantageous, since thereby a suitable network station will be proposed at an optimal geographical location. In practice, the network station might nevertheless have to be positioned at a

different location, for instance due to topographical reasons.

According to another preferred embodiment of this aspect of the invention, it is presumed that a single network station is only allowed to have a specific largest capacity. Therefore, an integer number of network stations are positioned at the point of balance. This integer number is at least equal to the sum of the estimated average amounts of resources exiting at the client points within the client cluster divided by the largest allowable capacity of a single network station. Thereby, specific technical limitations of the network stations can be modeled with further accuracy.

According to another preferred embodiment of this aspect of the invention, the client points are connected to the network station by performing the following actions: (i) connecting a first client point, which is located closest to the network station, and (ii) connecting the remaining client points in increasing radial order from the network station, such that each client point is connected to either of an already connected client point and the network station whichever is geographically closest to this particular client point.

According to another preferred embodiment of this aspect of the invention, the network stations are connected to the at least one feeding point by performing the following actions. First, a particular network station is associated to the feeding point that serves the station area within which the client points connected to the network station are positioned. Then, for each feeding point, a network station node list is formed over the network stations which are associated with the feeding point. The network station node list specifies for each network station: (1) a radial distance to the feeding point, and (2) an angular measure, which reflects an angular coordinate between the network station and a network station being located at a next larger and/or a next smaller angular degree in relation to the feeding point. The network station node list is arranged in an increasing



radius order, such that a first entry represents the network station being located at a smallest radial distance from the feeding point, a second entry represents a network station being located at a second smallest radial distance from the feeding point and so on. A currently topmost network station in the network station node list is connected to the feeding point, either directly or via another network station depending on which is located geographically closest to this yet unconnected network station. As soon as a network station has been connected, it is deleted from the station node list, such that a network station at a next larger radial distance to the feeding point instead becomes the topmost entry in the list. The network stations are continued to be connected accordingly until the network station node list is empty. Client points whose estimated average resource demand is in the order of the capacity of a typical network station are preferably treated as network stations. Hence, such client points are included at appropriate positions in the station node list as if they were network stations. This connection procedure is advantageous because it efficiently groups together those network stations (and thereby also client points) which preferably should be served by the same feeding point, i.e. be jointly linked to a closest higher hierarchical level in the network.

According to another preferred embodiment of this aspect of the invention, the processing involves calculating a density measure, which represents an average investment per client point required to build a physical network according to the generated network configuration. Preferably, the density measure expresses a required connection length per client point. Thereby, a figure is obtained which is useful when assessing the efficiency of an existing network. The ratio between the calculated average investment per client point and a corresponding actual investment may namely serve as such an efficiency indicator.

According to another aspect of the invention, these objects are achieved by a computer program directly loadable into the

internal memory of a digital computer, comprising software for controlling the method described above when said program is run on a computer.

5 According to yet another aspect of the invention, these objects are achieved by a computer readable medium, having a program recorded thereon, where the program is to make a computer perform the method described above.

10 Besides serving as an exceptionally powerful network design tool, the invention presents an objective means to evaluate various properties of already existing resource distribution networks. Particularly, the invention makes it possible to measure the utility added to a given network by a certain operator. This is a very important measure, for instance for regulatory authorities when considering subsidies or comparing  
15 pricing levels and other rate related quantities between different operators.

The invention described in this document proposes a strategy for configuring a network for distributing resources to a lowest hierarchical level, i.e. to end users. However, the invention is  
20 valid at an arbitrary higher or intermediate network level. For instance, the invention may be utilized for designing or evaluating national networks, region networks, primary networks as well as secondary networks for distribution of electrical energy.

25 In fact, the invention is applicable to any type of network where certain amounts of resources are to be allocated to each one of a number of clients. Thus, in addition to networks intended for distribution of electrical energy, water, sewerage, gas and heat respective allocation of resources for telecommunication and data traffic, the proposed solution may be applied to any other  
30 type of network which fulfills this condition.

# **BRIEF DESCRIPTION OF THE DRAWINGS**

The present invention is now to be explained more closely by means of preferred embodiments, which are disclosed as examples, and with reference to the attached drawings.

- 5     **Figure 1**        shows a block diagram over a general system for configuring a resource distribution network according to the invention,
- Figure 2**        illustrates schematically how station areas are formed around feeding points according to an embodiment of the invention,
- 10                   **Figure 3**        illustrates how the client points within the station areas are linked up to a relevant feeding point according to an embodiment of the invention,
- Figures 4a,b**    illustrate schematically how sub-networks are divided off from preliminary sub-networks within the station areas according to an embodiment of the invention,
- 15                   **Figure 5**        illustrates a proposed method of ranking client points based on their angular position in relation to a point of balance according to an embodiment of the invention,
- 20                   **Figure 6a**        shows ranking lists according to an embodiment of the invention where the client points of figure 5 are arranged in rising respective falling order regarding their angular positions in relation to the point of balance,
- 25                   **Figure 6b**        shows a group node list over the client points in figure 5 where the client points are arranged in increasing radius order from the point of balance,
- 30     **Figure 7a**        illustrates a first step through which, according to an embodiment of the invention, a first client

cluster is formed based on the group node list of figure 6b,

Figure 7b illustrates a second step through which the first client cluster of figure 7a is formed according to an embodiment of the invention,

**Figure 7c** illustrates a procedural stage in the proposed clustering procedure where a second client cluster is formed according to an embodiment of the invention,

10    Figures 8a-c illustrate how the client points of figure 7c are connected to a respective network station according to an embodiment of the invention,

15      Figure 9a      shows a group of client points in a sub-network where the client points' radial distances are indicated from a point of balance regarding the geographical positions and estimated average amounts of resources exiting at the client points within the sub-network,

Figure 9b illustrates an angular measure which reflects a relationship between the client points of figure 9a and the point of balance according to an embodiment of the invention,

25      **Figure 9c**      shows a connection node list according to an embodiment of the invention on basis of which the client points of figure 9a are connected to a network station,

**Figures 10a,b illustrate the working principle of a proposed connection algorithm,**

30      **Figure 11**      shows a graph over a cost function which may be applied when calculating a proposed cost measure,

Figure 12 shows an exemplary graph over a degree of network utilization as a function of the number of client points, and

5 Figure 13 illustrates, by means of a flow diagram, the general method for configuring a resource distribution network according to the invention.

### DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

10 A block diagram over a general system for configuring a resource distribution network according to the invention is shown in figure 1. It is here presumed that the resources enter via at least one feeding point and exit at a plurality of client points. A supply node list 110a contains a first set of coordinate data, which for each of the at least one feeding point designates a geographical position  $X_1$ ,  $Y_1$  and a respective amount of resources  $A_1$  fed into the network. Similarly, a user node list 110b contains a second set of coordinate data, which for each client point designates a geographical position  $x_1$ ,  $y_1$  and a respective estimated average amount of resources  $a_1$  exiting at the client point. A first data input means 120a is adapted to receive the supply node list 110a and forward the data therein to a digital processor 130. A second data input means 120b is adapted to receive the user node list 110b and forward the data therein to the digital processor 130. The first and second data input means 25 120a and 120b are constituted by any computer device through which data may be entered manually or automatically for digital processing. Consequently, a keyboard, a touch screen, a voice recognition interface, an OCR (Optical Character Recognition)-scanner, a disk drive system, a CD-ROM (Compact Disc-Read Only Memory)-drive, a hard disk and interfaces towards communication networks represent examples or such data input means. Furthermore, one and the same input means may be utilized for entering both the supply node list 110a and the user

node list 110b. In fact, it is preferable if the first and the second data input means 120a and 120b are identical.

The digital processor 130 processes the supply node list 110a and the user node list 110b, such that a network configuration  
5 150 is generated where each client point is connected to a particular feeding point, either directly or via at least one other client point. The description of the generated network configuration 150 is delivered via a data output means 140, which in analogy with the data input means 120a and 120b is constituted by any  
10 computer device through which digital data may be presented on a format that is adapted for human comprehension. Thus, the data output means 140 may for example be a text screen, a graphical display or an acoustic interface.

Figure 2 illustrates schematically how station areas  $SA_1$ ,  $SA_2$ ,  
15  $SA_3$  and  $SA_4$  are formed around feeding points  $F_1$ ,  $F_2$ ,  $F_3$  and  $F_4$  respectively by means of a proposed sectioning procedure. This procedure implies that the station areas  $SA_1$ - $SA_4$  are primarily given such boundaries that a specific client point (which each is illustrated by a star symbol) falls within the station area  $SA_1$ - $SA_4$   
20 whose associated feeding point  $F_1$ ,  $F_2$ ,  $F_3$  or  $F_4$  is closest to that client point. However, if the sum of resources exiting at the client points, which are thus associated to a feeding point is estimated to exceed this point's capacity, a sufficiently large fraction of the client points are instead associated to a second  
25 closest feeding point. Preferably, the fraction only includes client points that are located relatively close to a station area boundary. Thereby, comparatively short distances between the client points and the feeding points  $F_1$ - $F_4$  are granted. This, in turn, is one of the requirements for an efficient network configuration.  
30

Figure 3 illustrates how the client points within each of the station areas  $SA_1$ - $SA_4$  are linked up to the relevant feeding point  $F_1$ - $F_4$  by means of so-called a district grouping procedure. A station area  $SA_4$  is here used as an elucidating example.

The district grouping procedure involves determining a point of balance  $CB_4$  with respect to the geographical positions and estimated average amounts of resources exiting at the client points  $f_1$ - $f_{13}$  within the station area  $SA_4$ . According to an alternative embodiment of the invention, the point of balance  $CB_4$  is not the actual point of balance, however it is instead a designated geographical position, which may be chosen in consideration of topographical circumstances. In any case, a first client point  $f_6$  being geographically closest to the point of balance  $CB_4$  is identified and defined as being "connected". Typically, the actual point of balance  $CB_4$  does not coincide with the first client point's  $f_6$  position. Then, a second client point  $f_5$  being geographically second closest to the point of balance  $CB_4$  is linked up to the first client point  $f_6$ . The second client point  $f_5$  is thereby also defined as "connected" via the link to the already connected first client point  $f_6$ .

After that, a third client point  $f_7$  being geographically third closest to the point of balance  $CB_4$  is identified, whereafter first and second distances are determined between this point  $f_7$  and the first client point  $f_6$  and the second client point  $f_5$  respectively. The shortest of the first and the second distances determines to which of the first  $f_6$  and the second  $f_5$  client points that the third client point  $f_7$  is linked up. Here, the first distance between the third client point  $f_7$  and the first client point  $f_6$  is shorter than the second distance between the third client point  $f_7$  and the second client point  $f_5$ . Consequently, the third client point  $f_7$  is linked up to the first client point  $f_6$  and is thereby also defined as "connected".

The procedure then continues accordingly until all the client points  $f_1$ - $f_{13}$  within the station area  $SA_4$  are interconnected, such that they form a preliminary sub-network  $N_4$ . Corresponding preliminary sub-networks  $N_1$ ,  $N_2$  and  $N_3$  are formed in the other station areas  $SA_1$ ,  $SA_2$  and  $SA_3$  according to the same district grouping procedure.

Figure 4a shows the station areas  $SA_1$ - $SA_4$  of figure 3 and their associated preliminary sub-networks  $N_1$ - $N_4$ . A threshold distance  $D_{th}$  is defined, which represents a maximal distance that is allowed between two points in the network (i.e. between two client points or between a client point and a different type of node, such as a network station). The threshold distance  $D_{th}$  may be determined on basis of safety and/or quality factors. For instance, in case the resource distribution network transports electrical energy, the threshold distance  $D_{th}$  typically depends on a longest acceptable fuse release time and a largest acceptable voltage drop (say 10%). When instead water is transported, the threshold distance  $D_{th}$  is typically established based on a longest allowable connection without intermediary safety valves and a minimum refreshing rate. In the sewerage case, corresponding conditions may be established in consideration of safety and sanitary. Likewise for gas or district heating, requirements in terms of flow, safety and/or energy losses determine the threshold distance  $D_{th}$ .

Nevertheless, a sub-network is divided off from a relevant preliminary sub-network wherever the length of a connection between two network points exceeds the threshold distance  $D_{th}$ . In this example, a first preliminary sub-network  $N_1$  in a first station area  $SA_1$  is accordingly divided into two sub-networks  $N_{11}$  and  $N_{12}$  because a connection between client points  $f_{14}$  and  $f_{15}$  exceeds the threshold distance  $D_{th}$ , a second preliminary sub-network  $N_2$  in a second station area  $SA_2$  is likewise divided into new sub-networks  $N_{21}$  and  $N_{22}$  because a connection between client points  $f_{16}$  and  $f_{17}$  exceeds the threshold distance  $D_{th}$  and a fourth preliminary sub-network  $N_4$  in a fourth station area  $SA_4$  is finally divided into two sub-networks  $N_{41}$  and  $N_{42}$  because a connection between client points  $f_8$  and  $f_{12}$  exceeds the threshold distance  $D_{th}$ . However, a third preliminary sub-network  $N_3$  in a third station area  $SA_3$  remains intact because here no connection exceeds the threshold distance  $D_{th}$ . Hence, the sub-network in this area becomes identical with the preliminary sub-



network  $N_3$ . The resulting sub-networks  $N_{11}$ ,  $N_{12}$ ,  $N_{21}$ ,  $N_{22}$ ,  $N_3$ ,  $N_{41}$  and  $N_{42}$  in the station areas  $SA_1$ - $SA_4$  are shown in figure 4b.

Figure 5 illustrates a proposed method of ranking client points based on their angular position in relation to a point of balance  $CB_4$  according to an embodiment of the invention. The client points  $f_1$ - $f_{11}$  in the sub-network  $N_{41}$  within the fourth station area  $SA_4$  of figure 4b are here used to illustrate the working principle of a proposed clustering procedure.

First, a point of balance  $CB_4$  is determined with respect to the geographical positions and estimated average amounts of resources that exit at the client points  $f_1$ - $f_{11}$  within the sub-network  $N_{41}$ . A first client point  $f_1$  being located at a longest radial distance  $r_1$  from the point of balance  $CB_4$  is then identified and a first angular measure, which reflects an angular coordinate to this client point  $f_1$  is registered (i.e. the angular coordinate describes a relationship between the point of balance  $CB_4$  and the first client point  $f_1$ ). After that, a client point  $f_3$  being closest to the first client point  $f_1$  in terms of a positive angular measure  $\alpha^+$  in relation to the point of balance  $CB_4$  is identified. Subsequently, a client point  $f_4$  is identified, which in turn is closest to this client point  $f_3$  in terms of the positive angular measure  $\alpha^+$  in relation to the point of balance  $CB_4$ , and so on up to a last client point  $f_2$ . Preferably, a corresponding linkage is determined between the client points  $f_1$ - $f_{11}$  also in terms of a negative angular measure  $\alpha^-$  in relation to the point of balance  $CB_4$ . This listing may start with the client point  $f_2$  and end with the client point  $f_1$ . Figure 6a shows two such ranking lists over the client points  $f_1$ - $f_{11}$ , which are arranged in rising angular order  $\alpha^+$  from  $f_1$  to  $f_2$  respective in falling angular order  $\alpha^-$  from  $f_2$  to  $f_1$  regarding their angular positions in relation to the point of balance  $CB_4$ . Moreover, both the ranking lists are cyclic, such that the last element ( $f_2$  and  $f_1$  respectively) links further to the first element ( $f_1$  and  $f_2$  respectively).

Based on the client points'  $f_1$ - $f_{11}$  radial distances  $r_i$  from the

point of balance  $CB_4$  and the ranking lists of figure 6a a group node list is formed over the client points  $f_1$ - $f_{11}$  within the sub-network  $N_{41}$ . Figure 6b shows such a group node list 610, where the client points are arranged in an increasing radius order from the point of balance  $CB_4$ . A first entry in the list 610 thus represents the client point  $f_6$ , being located at a smallest radial distance from the point of balance  $CB_4$ , a second entry represents a client point  $f_5$  being located at a second smallest radial distance from the point of balance  $CB_4$ , and so on down to the client point  $f_1$  being located at the longest distance from the point of balance  $CB_4$ . The first entry in group node list 610 (i.e. the client point  $f_6$ ) is then defined as representing an artificial point of balance and is therefore instead denoted  $f_6^{CB}$ . A leftmost column specifies, for each client point  $f_i$ , the identity of a client point being located closest to the client point  $f_i$  in terms of the negative angular measure  $\alpha^-$ , and a rightmost column correspondingly specifies the identity of a client point being located closest to the client point  $f_i$  in terms of the positive angular measure  $\alpha^+$ .

Figure 7a illustrates how a first client cluster  $C_1$  is defined based on the group node list 610 of figure 6b according to an embodiment of the invention. A currently last client point in the group node list 610, i.e. the client point  $f_1$ , is assigned to a first element in the first client cluster  $C_1$ . The client point  $f_1$  is thereby also removed from the group node list 610. Consequently, the client point  $f_{10}$  now becomes the last client point in the group node list 610.

According to a search procedure, which is described in detail below with reference to figures 9a-c and 10a-b respectively, a client point  $f_2$  is identified as being located geographically closest to the client point  $f_1$ . Therefore, the client point  $f_2$  is provisionally assigned to be a yet later element in the first client cluster  $C_1$ . In order to test whether the client point  $f_2$  fulfills a boundary condition, such as being sufficiently close to the client point  $f_1$  in order to actually be assigned to the first client cluster

- $C_1$ , a first temporary point of balance  $CB_{12}^T$  is determined with respect to the geographical positions and estimated average amounts of resources that exit at the client points  $f_1$  and  $f_2$ . The client point  $f_2$  turns out to be located within a threshold distance  $D_{th}$  from the first temporary point of balance  $CB_{12}^T$ . Therefore, the client point  $f_2$  is assigned to be a yet later element in the first client cluster  $C_1$  and is consequently also removed from the group node list 610. However, the client point  $f_{10}$  remains the last client point in the group node list 610.
- The clustering procedure now continues to test if any additional client points may be assigned to the first client cluster  $C_1$ . To this aim, a new search is performed in order to find a client point being located geographically second closest to the client point  $f_1$ . This search encounters a client point  $f_3$ , which is not yet assigned to the first client cluster  $C_1$ . In order to test whether the client point  $f_3$  is sufficiently close to the already clustered client points  $f_1$  and  $f_2$ , such that it may be assigned to the first client cluster  $C_1$ , a second temporary point of balance  $CB_{123}^T$  is determined with respect to the geographical positions and estimated average amounts of resources that exit at the client points  $f_1$ ,  $f_2$  and  $f_3$ . Here, the client point  $f_3$  turns out to be located within the threshold distance  $D_{th}$  from the second temporary point of balance  $CB_{123}^T$ . Therefore, the client point  $f_3$  is assigned to be a yet later element in the first client cluster  $C_1$  and is consequently also removed from the group node list 610. This is illustrated in figure 7b. Preferably, the positions of the first temporary point of balance  $CB_{12}^T$  and the second temporary point of balance  $CB_{123}^T$  depend on a non-linear summation of the estimated average amounts of resources that exit at the client points  $f_1$ ,  $f_2$  and  $f_1$ ,  $f_2$  and  $f_3$  respectively. This summation principle will be discussed in more detail below with reference to figure 12.
- In order to test whether any additional client points can be included in the first client cluster  $C_1$ , yet a search is performed in respect of a not yet clustered client point, which at least

fulfills the distance-boundary requirement. However, no client point is found which is located within the threshold distance  $D_{th}$  from the relevant points of balance. Therefore no further client points can be included in the first client cluster  $C_1$ , and the first client cluster  $C_1$  is defined as being "full".

A second client cluster  $C_2$  is now created in which the currently last client point in the group node list 610, i.e. the client point  $f_{10}$ , is assigned to be a first element. Figure 7c illustrates the establishment of this client cluster  $C_2$ . The addition of the client point  $f_{10}$  to the second client cluster  $C_2$  renders the client point  $f_9$  the last client point in the group node list 610. (Namely, the client point  $f_2$  is already included in the first client cluster  $C_1$ .)

A following search identifies a client point  $f_9$  as being located geographically closest to the client point  $f_{10}$ . It is therefore tested whether this client point  $f_9$  fulfills the boundary condition. A temporary point of balance is therefore determined with respect to the geographical positions and estimated average amounts of resources that exit at the client points  $f_{10}$  and  $f_9$ . As mentioned earlier, the position of the temporary point of balance preferably depends on a non-linear summation of the estimated average amounts of resources that exit at the client points  $f_{10}$  and  $f_9$ . It here turns out that the client point  $f_9$  lies within the threshold distance  $D_{th}$  range from the temporary point of balance, and for that reason, the client point  $f_9$  is assigned to the second client cluster  $C_2$  as a second element. However, no further client points are found which are located within the threshold distance  $D_{th}$  from a relevant temporary points of balance with respect to the second client cluster  $C_2$ . Hence, the second client cluster  $C_2$  (including the client points  $f_{10}$  and  $f_9$ ) is now also defined as being "full".

The procedure then continues with third client cluster  $C_3$  where the client point  $f_8$  becomes the first element (since the client point  $f_9$  already has been added to the second client cluster  $C_2$ ) and so on until all the client points  $f_1$ - $f_{11}$  in the fourth station

area  $SA_4$  have been assigned to a client cluster. Figure 8a illustrates this stage in the clustering procedure, where in total five client clusters have been created, and a respective network station  $NS_1$ - $NS_5$  has been allocated to these clusters. As a further illustration, a column  $C_j$  to the right of the group node list 610 in figure 6b and an adjacent sequence diagram illustrate how and in which order the five client clusters  $C_1$ - $C_5$  are formed.

According to a preferred embodiment of the invention, the clustering algorithm checks whether a client point that is assigned to a particular client cluster is the artificial point of balance (i.e. in this example  $f_6^{CB}$ ). If this is the case, a new artificial point of balance is selected as the client point being closest to the point of balance  $CB_4$ , which is not yet assigned to a cluster. The procedure then continues as described above, however with this new artificial point of balance as a reference. Alternatively, the clustering procedure may subsequently continue according to a different principle. However, this will be described in detail at the end of this disclosure.

According to a preferred embodiment of the invention, a second boundary condition is defined, which in addition to the threshold distance  $D_{th}$ , implies that the sum of the estimated average amounts of resources exiting at the client points within a certain client cluster must be less than a threshold amount. Therefore, prior to adding a client point to a specific cluster, it is also tested whether the client point can be added without exceeding this threshold amount. If this cannot be done, the cluster is likewise defined as "full". Typically, the threshold amount represents a maximum allowed amount of resources delivered via a single network resource, such as a local transformer station in an electrical energy supply network. Preferably, the second boundary condition is tested in consideration of the non-linear summation function illustrated in figure 12.

In figure 8a the network station  $NS_1$ - $NS_5$  in each client cluster  $C_1$ - $C_5$  is positioned at the point of balance regarding the

geographical locations and estimated average amounts of resources exiting at the client points  $f_1$ - $f_{11}$  within that particular client cluster  $C_1$ - $C_5$ . Moreover, the network station  $NS_1$ - $NS_5$  is assigned a capacity, which is sufficient with respect to the sum of the estimated average amounts of resources exiting at these client points  $f_1, f_2, f_3; f_9, f_{10}; f_7, f_8; f_4, f_{11}$  and  $f_5, f_6$  respectively.

According to a preferred embodiment of the invention, instead of just a single network station, an integer number (larger than one) of network stations  $NS_1$ - $NS_5$  are positioned at the relevant point of balance. Again, this may be necessary when a maximum allowed amount of resources delivered via single network resource has been defined. The integer number is, of course, at least equal to the sum of the estimated average amounts of resources exiting at the client points within the client cluster in question divided by the largest allowable capacity of a single network station.

Figure 8b shows a set of first level networks resulting from an initial stage of the proposed connection procedure where each of the client points  $f_1$ - $f_{11}$  has been connected to a network station  $NS_1$ - $NS_5$  that is allocated to the client cluster  $C_1$ - $C_5$  to which the client point  $f_1$ - $f_{11}$  belongs.

Figure 8c shows a resulting network after completion of a following stage in the connection procedure where each of the network stations  $NS_1$ - $NS_5$  in turn have been interconnected and been further connected to a feeding point  $F_4$  for the station area ( $SA_4$  in figure 3) within which the client points  $f_1$ - $f_{11}$  are located. The principles of the proposed connection procedure are basically the same as the for the district grouping and clustering procedures. One exception, of course, is that during the clustering procedure the algorithm finds the closest client point, however it is not tested whether this point is connected. Nevertheless, the connection procedure will be discussed in detail below with reference to figures 9a-c and 10a-b. Therefore, the procedure is given a higher-level description below.

Figure 9a shows a group of client points  $f_a-f_k$  in a sub-network where the client points'  $f_a-f_k$  radial distances from a point of balance CB are indicated by means of concentric circle segments. For reasons of illustration, only some of the client points that determine the location of the point of balance CB are shown in the figure. (This explains why the point of balance CB appears to be shifted in relation to the depicted client points  $f_a-f_k$ .) Nevertheless, as is apparent from the figure, a client point  $f_a$  is located geographically closest to the point of balance CB and a client point  $f_k$  is most remotely located from the point of balance CB.

Figure 9b again shows the group of client points  $f_a-f_k$  of figure 9a. Here however, the angular relationships between the client points' positions are indicated by means of a solid line, which interconnects those client points that are each other's neighbors with respect to angular measures  $\alpha^+$ ,  $\alpha^-$  in relation to the point of balance CB. A client point  $f_c$  is defined to have a lowest positive angular measure  $\alpha^+$  and a client point  $f_d$  is defined to have a corresponding lowest negative angular measure  $\alpha^-$ .

According to an embodiment of the invention, the nodes in the resource distribution network (i.e. the client points, the network stations and the feeding points) are interconnected according to a connection algorithm. Based on the client points'  $f_a-f_k$  different radial distances from the point of balance CB (as shown in figure 9a) and the angular relationships between the client points'  $f_a-f_k$  positions (as shown in figure 9b) a connection node list 910 is created. Figure 9c shows such a list where the client points  $f_a-f_k$  are arranged in increasing radial distance from the point of balance CB. The connection node list 910 thus starts with the client point  $f_a$  and ends with the client point  $f_k$ . The connection node list 910 also contains information pertaining to the angular neighbors to each client points  $f_a-f_k$  as derived from the angular relationships illustrated in figure 9b. The two boxes that contain dashed lines represent two of the client points which are not illustrated in figures 9a and 9b, however influence

the position of the point of balance CB.

Referring to the client points  $f_a-f_k$  of figure 9a, figures 10a and b illustrate the working principle of the connection algorithm according to an embodiment of the invention. The client point  $f_a$  being located closest to a serving network station NS (i.e. the first entry in the client connection node list) is the first client point  $f_a$  to be connected to this network station NS. The network station NS is preferably positioned where the point of balance CB was determined to be located in figure 9a. After having connected the first client point  $f_a$ , the remaining client points  $f_b-f_k$  are connected in increasing radial order from the network station NS. The rule given by the algorithm is that: "an unconnected client point shall be connected to another client point which is (i) geographically closest and (ii) is in turn already connected to the network station NS, either directly or via another client station".

Figure 10a shows a situation where the client points  $f_a, f_b, f_c, f_d, f_e$  and  $f_f$  have already been connected to the network station NS in accordance with the algorithm and a client point  $f_g$  is in the process of being connected. The client point  $f_g$  is located at a radial distance  $r_g$  from the network station NS. Due to the proposed connection order, this means that all the connected client points  $f_a-f_f$  are located at a shorter radial distance ( $r_a < r_b < r_c < r_d < r_e < r_f < r_g$ ) from the network station NS than  $r_g$ . Hence, any connection candidates for the client point  $f_g$  are to be found within a circle with a radius  $r_g$  from the network station NS. The search for such candidate client points starts with a scan in a positive angular direction  $\alpha^+$  from the client point  $f_g$  in relation to the position of the network station NS, and the search ends when an angle  $\alpha^+ = \alpha^+_{\max} = 60^\circ$  is reached. Namely, at this angle the distance between the client point  $f_g$  and a possible connection candidate client point equals the radius  $r_g$ . Thus, if no connected client points have been found within this range, the client point  $f_g$  may equally well be connected directly to the network station NS. In this example, however, a first connection



candidate client point  $f_e$  is found at a distance  $d_{g-e} < r_g$  from the client point  $f_g$ . Relevant information pertaining to this first connection candidate  $f_e$  is therefore stored.

- 5 Then, the scan for candidate client points is repeated, however now in a negative angular direction  $\alpha^-$  from the client point  $f_g$  in relation to the position of the network station NS. Also here the search ends when an angle  $\alpha^- = \alpha^-_{max} = 60^\circ$  is reached. Within this range, a second connection candidate client point  $f_f$  is found at a distance  $d_{g-f} < r_g$  from the client point  $f_g$ . Hence, relevant
- 10 information pertaining to the second connection candidate  $f_f$  is also stored. The distances  $d_{g-f}$  and  $d_{g-e}$  are compared with each other and the client point  $f_g$  is connected to the closest of the two encountered candidate client points, which in this example turns out to be the client point  $f_e$  (because  $d_{g-e} < d_{g-f}$ ).
- 15 Subsequently, the procedure continues according to these principles until also the client point  $f_h-f_k$  have been connected.

- Moreover, according to the invention, the connection algorithm described above is applied when connecting the network stations to the feeding stations. One exception, however, is that
- 20 the feeding point cannot normally be placed at a point of balance in relation to the load generated by the network stations and their geographical positions. Instead, the feeding point's position as given by the supply node list will be used. Although theoretically, it is conceivable that also the position of the feeding
- 25 points may be altered at this stage.

- According to a preferred embodiment of the invention, the network stations are interconnected, and in turn connected to at least one feeding point along the following lines. A particular network station is associated to the feeding point which serves
- 30 the station area within which the network station is located. In other words, the client points determine to which feeding point a certain network station shall be associated, such that the network station is associated with the same feeding point as the client points within that station area.

A network station node list is then formed over the network stations being associated with the feeding point in question. For each network station this list specifies: a radial distance to the feeding point, and an angular measure that reflects an angular coordinate between the network station and a network station being located at a next larger and/or a next smaller angular degree in relation to the feeding point. The list is arranged in an increasing radius order, such that a first entry represents the network station being located at a smallest radial distance from the feeding point, a second entry represents a network station being located at a second smallest radial distance from the feeding point and so on. A currently topmost network station in the list is connected to the feeding point, either directly or via another network station depending on which is located geographically closest to the network station. Thereafter, the network station is deleted from the network station node list after having been thus connected. The network stations are connected accordingly until network station node list is empty, and consequently all the network stations within the particular station area have been connected to the relevant feeding point.

According to a preferred embodiment of the invention, at least one processing step in addition to the processing necessary to generate the proposed network configuration is included. This step involves calculating a density measure, which represents an average investment per client point that is required to build a physical network according to the generated network configuration. Preferably, the density measure expresses a required connection length per client point. Figure 11 shows a graph over a cost function, which may be applied when calculating this measure in order to increase the accuracy of the cost estimate. A cost per length unit  $C_{st}/l.u.$ , say USD/meter, here varies with a connection length per client point  $c.l./f$ , such that the cost per length unit  $C_{st}/l.u.$  falls from an initial value  $C_{st_0}$  representing a basic investment to an asymptotic value  $C_{st_c}$ , which is approached for high connection lengths per client point  $c.l./f$ .

(i.e. low densities). It has been found empirically that a typical cost function of this type is well described by means of a tangens hyperbolicus function.

As mentioned initially, due to partial time-overlap between the loads generated by each of a plurality of client points, the combined load created by a group of client points is generally different from a linear summation of the individual loads. Figure 12 shows an exemplary graph, which models this condition. The graph describes a degree of network utilization  $t$  [h/year] as a function of the number of client points  $\#f$ , which is preferably applied both when associating the client points to the station areas and in the proposed clustering step when two or more client points are associated to each other, such that a sub-network is formed within the station area to which the client points belong. Thereby, the size of the station areas as well as the capacity of the network stations can be determined more accurately.

In order to sum up, the general method for configuring a resource distribution network according to the invention will now be described with reference to the flow diagram in figure 13.

A first step 1310 receives a supply node list containing a first set of coordinate data, which for each of the at least one feeding point designates a geographical position and a respective amount of resources fed into the network. A second step 1320 receives a user node list containing a second set of coordinate data, which for each client point designates a geographical position and a respective estimated average amount of resources exiting at the client point. A step 1330 investigates whether both the supply node list and the user node list have been received, and if so, the procedure continues to a step 1340. Otherwise, the procedure loops back to the start and awaits any not yet received lists.

The step 1340 forms a station area around each feeding point.

The station areas are formed such that a specific client point falls within the station area whose associated feeding point is closest to the client point. According to a preferred embodiment of the invention, however, a sufficiently large fraction of the thus

5 associated client points are instead associated to a second closest feeding point if the estimated sum of resources exiting at the client points exceeds this feeding point's capacity. The fraction of client points can only be associated with the second

10 closest feeding point if its capacity so allows. Otherwise, the fraction of client points will have to be associated to a third closest feeding point, and so on. Subsequently, a step 1350 forms at least one sub-network within each station area. These sub-networks are formed according to a network segmenting algorithm. It is here worth mentioning that the step 1350 may be

15 empty or trivial, such that the at least one sub-network does not necessarily have to represent an actual network, however it may merely constitute a common reference to the client points within a particular station area. After that, a step 1360 forms one or more client clusters in which the client points in each station

20 area are associated with each other, such that two or more client points together form at least one client cluster within the sub-network to which they belong. A first connection step 1370 then connects the client points within each client cluster to a respective network station, whereafter a second connection step

25 1380 further connects the network stations to the at least one feeding point. Finally, a description of the generated network configuration is delivered in a step 1390.

All of the process steps, as well as any sub-sequence of steps, described with reference to the figure 13 above may be

30 controlled by means of a computer program being directly loadable into the internal memory of a computer, which includes appropriate software for controlling the necessary steps when the program is run on a computer. Furthermore, such computer program can be recorded onto arbitrary kind of computer

35 readable medium as well as be transmitted over arbitrary type of

network and transmission medium. For instance, the computer program may be loaded into a computer from a signal from the Internet.

5 According to a first alternative embodiment of the invention, the algorithm for the proposed clustering and connection procedures does not involve a shift of the point of balance to an artificial point of balance (such as from  $CB_4$  to  $f_6^{CB}$  in figures 7a-c). Instead, the actual point of balance (e.g.  $CB_4$  of figure 5) is maintained. Consequently, it will never be necessary to select a  
10 new artificial point of balance. This may be convenient for some applications. However, maintaining the actual point of balance will generally render the clustering a more time consuming process, particularly for station areas that include a very large number of client points.

15 According to a second alternative embodiment of the invention, the algorithm for the proposed clustering and connection procedures does not consider any angular relationships between the client points. Thus, in this embodiment, for instance, the  $\alpha^-$ - and  $\alpha^+$ -columns may be removed from the group node list 610 of  
20 figure 6b. Namely, only the radial ordering of the client points determine how the clustering procedure is effectuated. However, the procedure involves generating repeated listings over all unclustered client points with respect to their distances to a first element in each client cluster. Below follows a description of this  
25 alternative clustering procedure with reference to the client points  $f_1$ - $f_{11}$  of figure 5.

After having determined the point of balance  $CB_4$  with respect to the geographical positions and estimated average amounts of resources that exit at the client points  $f_1$ - $f_{11}$ , the client points are  
30 arranged in a group node list in increasing radial order from the point of balance  $CB_4$  (i.e. according to the  $f_i(r_i)$ -column in the group node list 610 of figure 6b). Then, the last element in the group node list (i.e. the client point  $f_1$ ) is assigned to a first client cluster  $C_1$  and is removed from the list, thus rendering the

client point  $f_{10}$  the last element in the group node list.

Subsequently, a listing is generated, which ranks all the client points in increasing radial order from the client point  $f_1$ . The client points  $f_2$ ,  $f_3$ ,  $f_5$ , and  $f_4$  respectively represent the first four entries in this listing. Hence, the client point  $f_2$  is identified as being geographically closest to the client point  $f_1$ , the client point  $f_3$  being second closest, and so on.

After that, a test is performed as to whether the client point  $f_2$  fulfills at least one boundary condition and thus may be added to the first client cluster  $C_1$ . The boundary condition typically involves determining a first temporary point of balance  $CB_{12}^T$  as described above with reference to figure 7a. According to a preferred embodiment of the invention, however, the boundary condition also involves testing against a threshold amount, i.e. if the sum of the estimated average amounts of resources exiting at the client points  $f_1$  and  $f_2$  exceeds the threshold amount. Provided that the client point  $f_2$  fulfills any such boundary conditions it is assigned to be a yet later element in the first client cluster  $C_1$ . The client point  $f_2$  is also removed from the group node list.

Then, the above boundary condition testing is repeated for the client point  $f_3$ . This client point  $f_3$  turns out to fulfill the boundary conditions and is consequently also assigned to the first client cluster  $C_1$  and removed from the group node list. The following entry in the listing, the client point  $f_5$ , however, fails the boundary condition test and therefore cannot be assigned to the first client cluster  $C_1$ .

Instead, a second client cluster  $C_2$  is formed where the currently last element in the group node list, i.e. client point  $f_{10}$ , is a first element. After that, a repeated listing is generated, which ranks all the client points in increasing radial order from the client point  $f_{10}$ . The client point  $f_9$ ,  $f_{11}$  and  $f_6$  respectively represent the first three entries in this listing. Hence, the client point  $f_9$  is

identified as being geographically closest to the client point  $f_{10}$ , the client point  $f_{11}$  being second closest, and so on.

5 The at least one boundary condition is then tested, new clusters are formed and repeated listings are generated accordingly until all the client points  $f_1$ - $f_{11}$  have been assigned to a client cluster  $C_1$ - $C_5$ , which is equivalent to the group node list being empty.

10 Finally, the above-described second alternative embodiment of the invention is also applicable as a viable alternative to the proposed connection algorithm in the district grouping procedure (which likewise involves an angular search for finding a next closest client point that is to be "connected").

15 The term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components. However, the term does not preclude the presence or addition of one or more additional features, integers, steps or components or groups thereof.

The invention is not restricted to the described embodiments in the figures, but may be varied freely within the scope of the claims.

Claims

1. A method of configuring a resource distribution network in which resources enter via at least one feeding point ( $F_1$ - $F_4$ ) and exit at a plurality of client points, the method comprising:

- 5 receiving, via a first data input means (120a), a supply node list (110a) containing a first set of coordinate data which for each of the at least one feeding point ( $F_1$ - $F_4$ ) designates a geographical position ( $X_1$ ,  $Y_1$ ) and a respective amount of resources ( $A_1$ ) fed into the network,
- 10 receiving, via a second data input means (120b), a user node list (110b) containing a second set of coordinate data which for each client point designates a geographical position ( $x_1$ ,  $y_1$ ) and a respective estimated average amount of resources ( $a_1$ ) exiting at the client point,
- 15 processing, in a digital processor (130), the supply node list (110a) and the user node list (110b), the processing generating a network configuration (150) where each client point is connected to a particular feeding point ( $F_1$ - $F_4$ ), either directly or via at least one other client point, and involving:
  - 20 a sectioning step through which a station area ( $SA_1$ - $SA_4$ ) is formed around each feeding point ( $F_1$ - $F_4$ ), the station areas ( $SA_1$ - $SA_4$ ) being formed such that a specific client point falls within the station area ( $SA_1$ - $SA_4$ ) whose associated feeding point ( $F_1$ - $F_4$ ) is closest to the client point,
  - 25 a grouping step through which at least one sub-network ( $N_{11}$ - $N_{42}$ ) is formed within each station area ( $SA_1$ - $SA_4$ ), the at least one sub-network ( $N_{11}$ - $N_{42}$ ) being formed according to a network segmenting algorithm,
  - 30 a clustering step through which the client points in each station area ( $SA_1$ - $SA_4$ ) are associated with each other such that two or more client points ( $f_1$ ,  $f_2$ ,  $f_3$ ;  $f_9$ ,  $f_{10}$ ;  $f_7$ ,  $f_8$ ;  $f_4$ ,  $f_{11}$ ;  $f_6$ ,  $f_6$ ) together form at least one client cluster ( $C_1$ - $C_5$ ) within the sub-network ( $N_{41}$ ) to which they belong, and
  - 35 a connection step through which a respective network station ( $NS_1$ - $NS_5$ ) is allocated to each client cluster ( $C_1$ -



5         $C_5$ ), the client points ( $f_1, f_2, f_3; f_9, f_{10}; f_7, f_8; f_4, f_{11}; f_5, f_6$ ) within each client cluster ( $C_1, C_2, C_3, C_4; C_5$ ) are connected to their respective network station ( $NS_1-NS_5$ ), and the network stations ( $NS_1-NS_5$ ) in turn are connected to a particular feeding point ( $F_4$ ) of the at least one feeding point ( $F_1-F_4$ ), and

delivering, via a data output means (140), a description of the generated network configuration (150).

10        2. A method for configuring a resource distribution network according to claim 1, characterized by the network segmenting algorithm being trivial such that the grouping step merely produces a listing over the client points within each station area ( $SA_1-SA_4$ ).

15        3. A method for configuring a resource distribution network according to any one of the claims 1 or 2, characterized by the grouping step comprising:

20        a district grouping sub-step through which each client point in each station area ( $SA_1-SA_4$ ) is linked up to the station area's feeding point ( $F_1-F_4$ ) such that a specific client point is linked up to the feeding point either directly or via at least one other client point.

25        4. A method for configuring a resource distribution network according to claim 3, characterized by the district grouping sub-step involving:

determining a point of balance ( $CB_4$ ) with respect to the geographical positions and estimated average amounts of resources exiting at the client points ( $f_1-f_{13}$ ) within the station area ( $SA_4$ ),

30        identifying a first client point ( $f_6$ ) being geographically closest to the point of balance ( $CB_4$ ),

defining the first client point ( $f_6$ ) as connected,

identifying a second client point ( $f_5$ ) being geographically

second closest to the point of balance ( $CB_4$ ),

defining the second client point ( $f_5$ ) as connected and being linked up to the first client point ( $f_6$ ),

identifying any not yet connected client points ( $f_1, f_2, f_3, f_4, f_5, f_8, f_9, f_{10}, f_{11}, f_{12}; f_{13}$ ) in increasing radial distance from the point of balance ( $CB_4$ ) and consecutively linking up each of these points ( $f_1, f_2, f_3, f_4, f_5, f_8, f_9, f_{10}, f_{11}, f_{12}; f_{13}$ ) to a respective closest connected client point ( $f_6; f_5$ ) until all the client points within the station area ( $SA_4$ ) are interconnected into a preliminary sub-network ( $N_4$ ).

5. A method for configuring a resource distribution network according to claim 3, characterized by the district grouping sub-step involving:

designating a point of balance with a particular geographical position,

identifying a first client point being geographically closest to the point of balance,

defining the first client point as connected,

identifying a second client point being geographically second closest to the point of balance,

defining the second client point as connected and being linked up to the first client point,

identifying any not yet connected client points in increasing radial distance from the point of balance and consecutively linking up each of these points to a respective closest connected client point until all the client points within the station area are interconnected into a preliminary sub-network.

6. A method for configuring a resource distribution network according to any one of the preceding claims, characterized by the network segmenting algorithm involving:

forming in the station area ( $SA_4$ ) a preliminary sub-network ( $N_4$ ) which interconnects all the client points therein,

dividing off a sub-network ( $N_{41}, N_{42}$ ) from the preliminary

sub-network ( $N_4$ ) wherever the length of a connection between two client points ( $f_8, f_{12}$ ) or between a client point and the feeding point exceeds a threshold distance ( $D_{th}$ ), and

forming a group node list (610) over the client points ( $f_1$ - $f_{11}$ ) within each respective sub-network ( $N_{41}$ ), the group node list (610) for each client point specifying:

a radial distance ( $r_1$ ) to a geographical position representing a point of balance (CB) regarding the geographical positions and estimated average amounts of resources exiting at the client points ( $f_1$ - $f_{11}$ ) within the sub-network ( $N_{41}$ ), and

an angular measure ( $\alpha^+, \alpha^-$ ) reflecting an angular coordinate between the client point and a client point being located at a next larger and/or a next smaller angular degree in relation to the point of balance ( $CB_4$ ),

the group node list (610) being arranged in an increasing radius order such that a first entry represents the client point ( $f_6^{CB}$ ) being located at a smallest radial distance from the point of balance (CB), a second entry represents a client point ( $f_5$ ) being located at a second smallest radial distance from the point of balance (CB) and so on.

7. A method for configuring a resource distribution network according to claim 6, characterized by the clustering step comprising:

assigning a currently last client point ( $f_1$ ) in the group node list (610) as a first element in a client cluster ( $C_1$ ) and removing the client point ( $f_1$ ) from the group node list (610),

assigning a later element in the client cluster ( $C_1$ ) as a client point ( $f_2$ ) being located geographically closest to the client point ( $f_1$ ) representing the first element, the later element being added provided that at least one boundary condition is fulfilled, otherwise the client cluster ( $C_1$ ) being defined as full and the later element instead constituting a first element in a new client cluster ( $C_2$ ), and

continuing to assign elements to client clusters ( $C_1$ - $C_5$ )

until all the client points ( $f_1$ - $f_{11}$ ) in the group node list (610) have been assigned to a client cluster ( $C_1$ - $C_5$ ).

8. A method for configuring a resource distribution network according to claim 7, characterized by the at least one  
5 boundary condition implying that a distance between two client points ( $f_1$ ,  $f_2$ ) connected to each other must be less than the threshold distance ( $D_{th}$ ).

9. A method for configuring a resource distribution network according to any one of the claims 7 or 8, characterized by the  
10 at least one boundary condition implying that a distance between a candidate client point ( $f_3$ ) to be added to a cluster ( $C_1$ ) and a temporary point of balance ( $CB^T_{123}$ ) with respect to the geographical positions and estimated average amounts of resources that exit at the client points ( $f_1$ ,  $f_2$ ) in the cluster ( $C_1$ )  
15 and the candidate client point ( $f_3$ ) must be less than the threshold distance ( $D_{th}$ ).

10. A method for configuring a resource distribution network according to any one of the claims 7 - 9, characterized by the  
20 at least one boundary condition implying that the sum of the estimated average amounts of resources exiting at the client points within a certain client cluster must be less than a threshold amount.

11. A method for configuring a resource distribution network according to claims 10, characterized by calculating the sum of  
25 the estimated average amounts of resources exiting at the client points in consideration of a non-linear resource summation function.

12. A method for configuring a resource distribution network according to any one of the claims 7 - 11, characterized by the

connection step comprising:

5 positioning the network station ( $NS_1$ - $NS_5$ ) at a geographical position representing a point of balance regarding the geographical positions and the estimated average amounts of resources exiting at the client points ( $f_1$ - $f_{11}$ ) within the client cluster ( $C_1$ ,  $C_2$ ,  $C_3$ ,  $C_4$ ;  $C_5$ ), and

10 assigning a capacity to the network station ( $NS_1$ - $NS_5$ ) being sufficient with respect to the sum of the estimated average amounts of resources exiting at these client points ( $f_1$ ,  $f_2$ ,  $f_3$ ;  $f_9$ ,  $f_{10}$ ;  $f_7$ ,  $f_8$ ;  $f_4$ ,  $f_{11}$ ;  $f_5$ ,  $f_6$ ).

13. A method for configuring a resource distribution network according to claims 12, characterized by assigning the capacity to the network station ( $NS_1$ - $NS_5$ ) in consideration of a non-linear resource summation function.

15 14. A method for configuring a resource distribution network according to any one of the claims 12 or 13, characterized by positioning an integer number of network stations ( $NS_1$ - $NS_5$ ) at the point of balance, the integer number at least being equal to the sum of the estimated average amounts of resources exiting  
20 at the client points ( $f_1$ ,  $f_2$ ,  $f_3$ ;  $f_9$ ,  $f_{10}$ ;  $f_7$ ,  $f_8$ ;  $f_4$ ,  $f_{11}$ ;  $f_5$ ,  $f_6$ ) within the client cluster ( $C_1$ ,  $C_2$ ,  $C_3$ ,  $C_4$ ;  $C_5$ ) divided by a largest allowable capacity of a single network station.

25 15. A method for configuring a resource distribution network according to any one of the claims 12 - 14, characterized by the connection of the client points ( $f_a$ - $f_k$ ) to the network stations (NS) comprising:

connecting a first client point ( $f_a$ ) being located closest to the network station (NS), and

30 connecting client points ( $f_b$ - $f_k$ ) being located more remote from the network station (NS) than the first client point ( $f_a$ ) in an increasing radial order from the network station (NS) such that each client point ( $f_b$ - $f_k$ ) is connected to either of an already con-

nected client point ( $f_a-f_j$ ) and the network station (NS) whichever is geographically closest to the client point ( $f_b-f_k$ ).

16. A method for configuring a resource distribution network according to any one of the preceding claims, characterized by  
5 the connection of the network stations to the at least one feeding point ( $F_1-F_4$ ) comprising:

associating a particular network station ( $NS_1-NS_5$ ) to the feeding point ( $F_4$ ) which serves the station area ( $SA_4$ ) within which the client points are located, which are connected to the  
10 network station ( $NS_1-NS_5$ ),

forming, for each feeding point ( $F_1-F_4$ ), a network station node list over the network stations being associated with the feeding point, the network station node list for each network station specifying:

15 a radial distance to the feeding point, and  
an angular measure reflecting an angular coordinate between the network station and a network station being located at a next larger and/or a next smaller angular degree in relation to the feeding point, the network station  
20 node list being arranged in an increasing radius order such that a first entry represents the network station being located at a smallest radial distance from the feeding point, a second entry represents a network station being located at a second smallest radial distance from the  
25 feeding point and so on,

connecting a currently topmost network station in the network station node list to the feeding point, either directly or via another network station depending on which is located geographically closest to the yet unconnected network station,

30 deleting any connected network stations from the network station node list, and

continuing to connect network stations until network station node list is empty.

17. A method for configuring a resource distribution network according to any one of the preceding claims, **characterized by** the processing involving:

- 5     calculating a density measure which represents an average investment per client point (f) required to build a physical network according to the generated network configuration (150).

18. A method for configuring a resource distribution network according to claim 17, **characterized by** the density measure expressing a required connection length per client point (f).

- 10   19. A method for configuring a resource distribution network according to claim 18, **characterized by** modifying the required connection length per client point (f) such that the required connection length per client point (f) increases with an increasing density measure.

- 15   20. A computer program directly loadable into the internal memory of a digital computer, comprising software for performing the steps of any of the claims 1 - 19 when said program is run on a computer.

- 20   21. A computer readable medium, having a program recorded thereon, where the program is to make a computer perform the steps of any of the claims 1 - 19.

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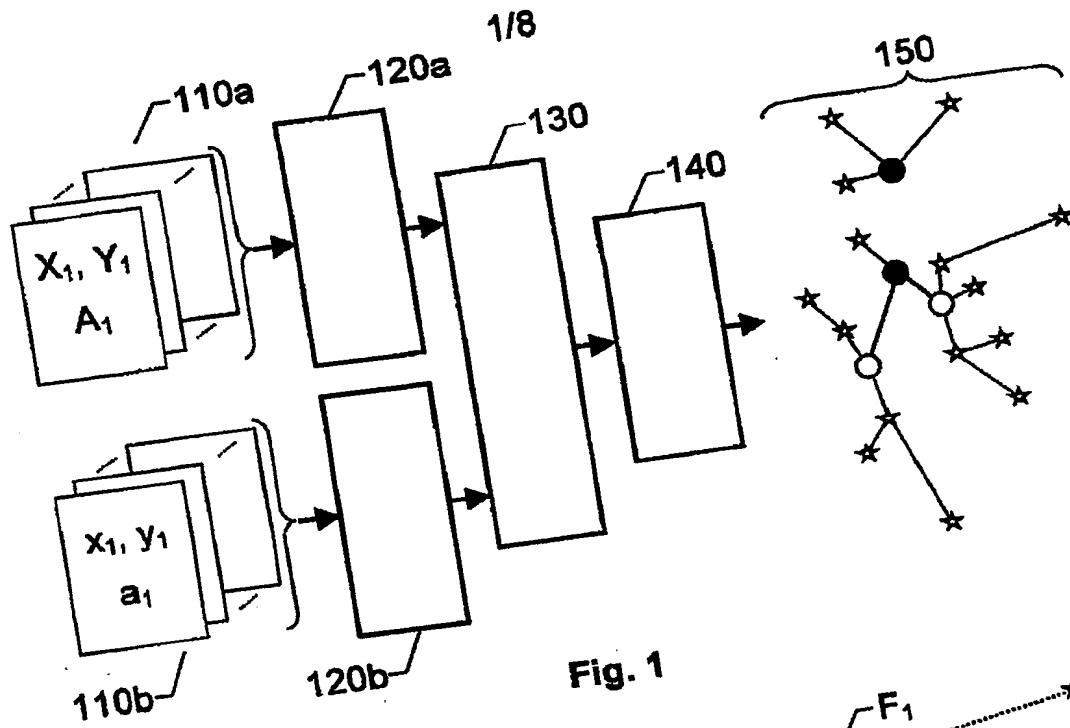
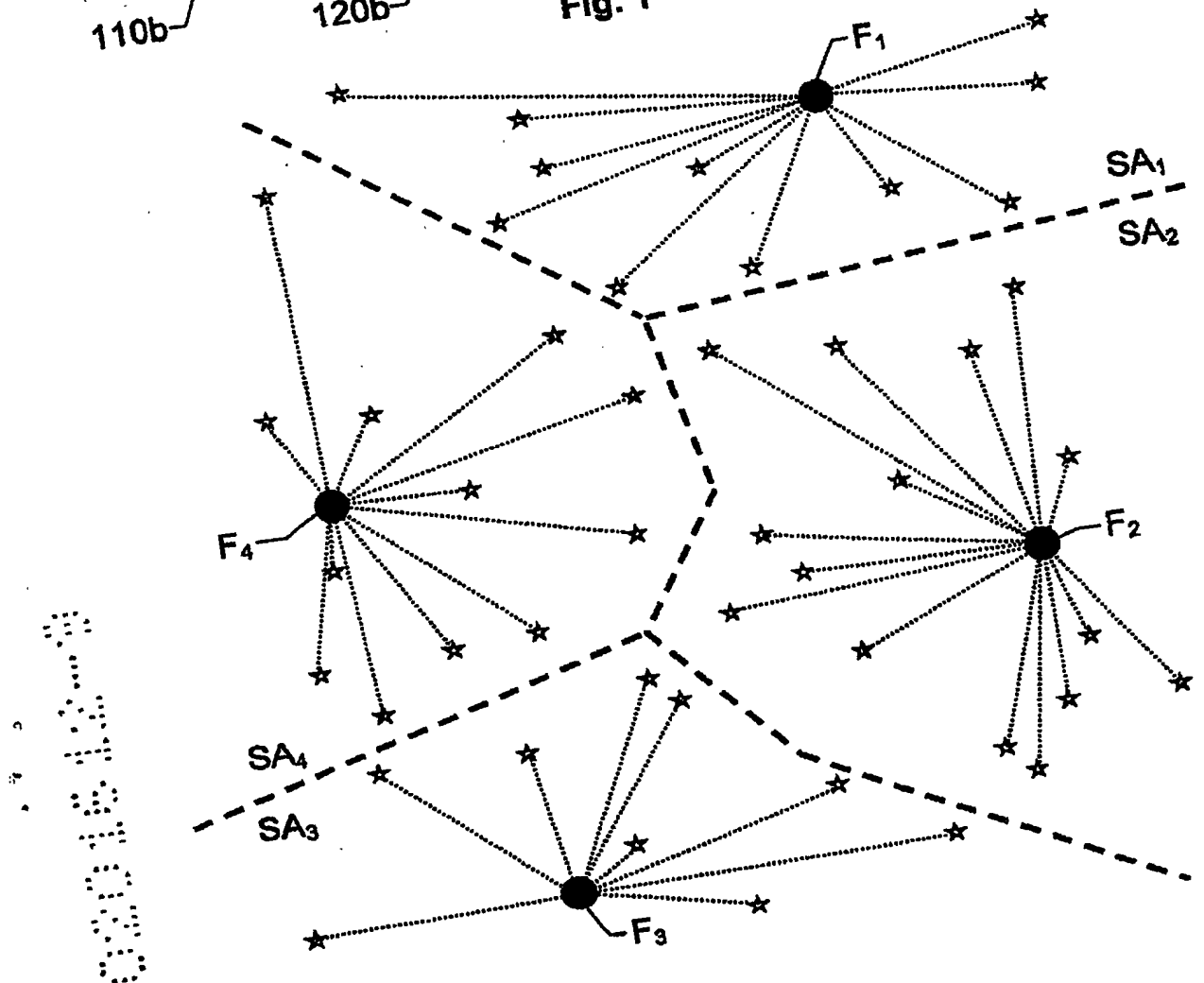


Fig. 1





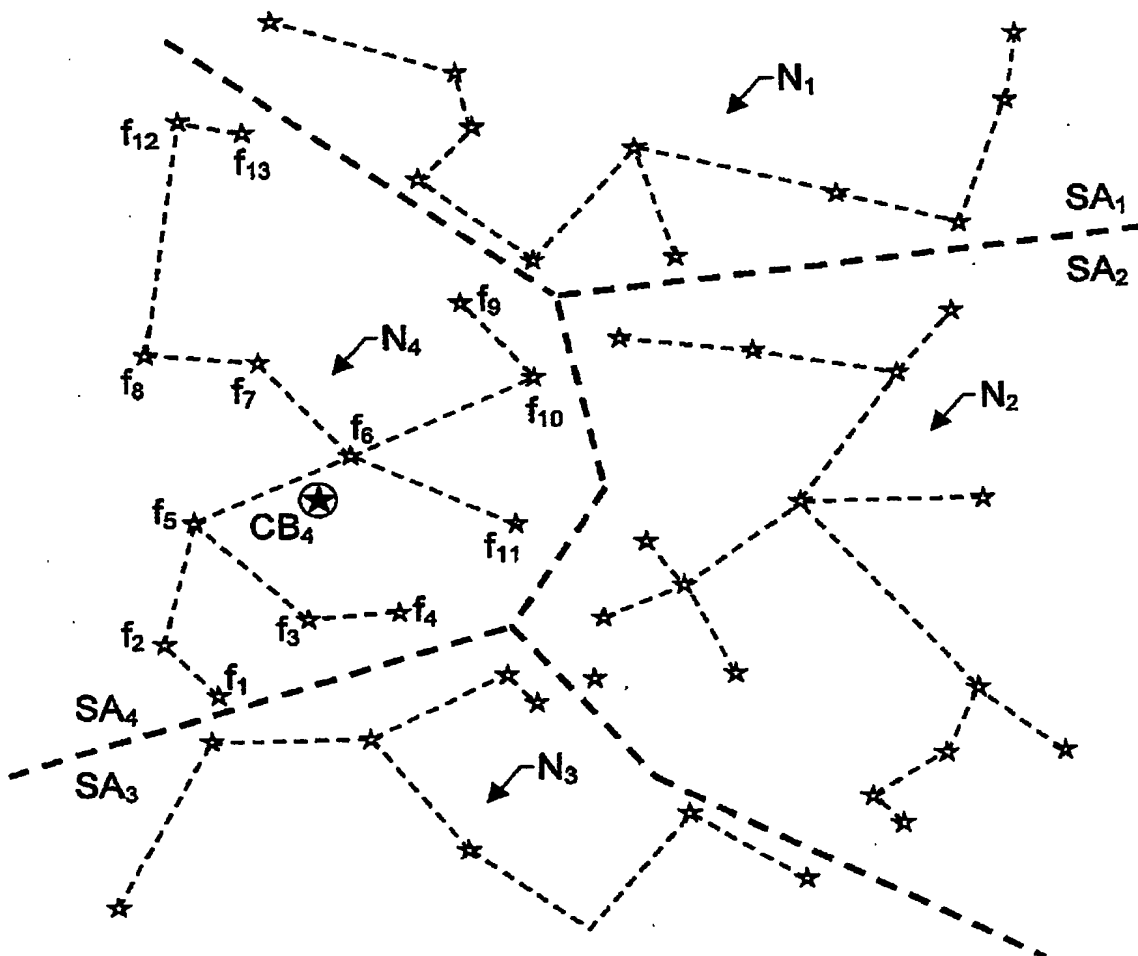


Fig. 3

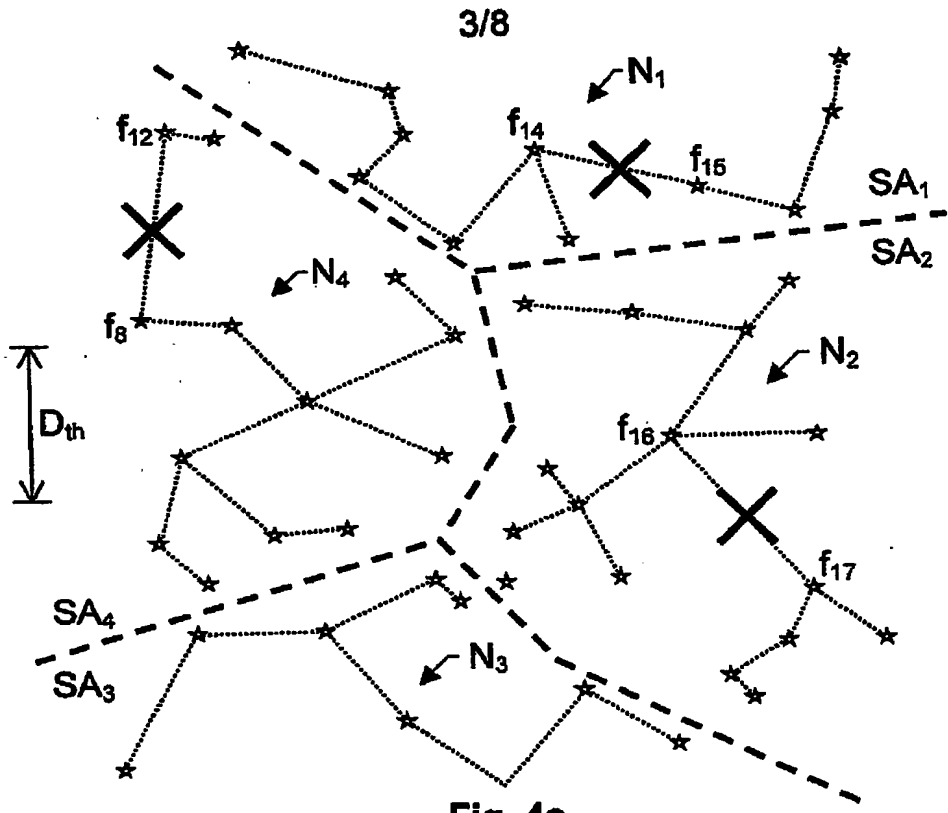
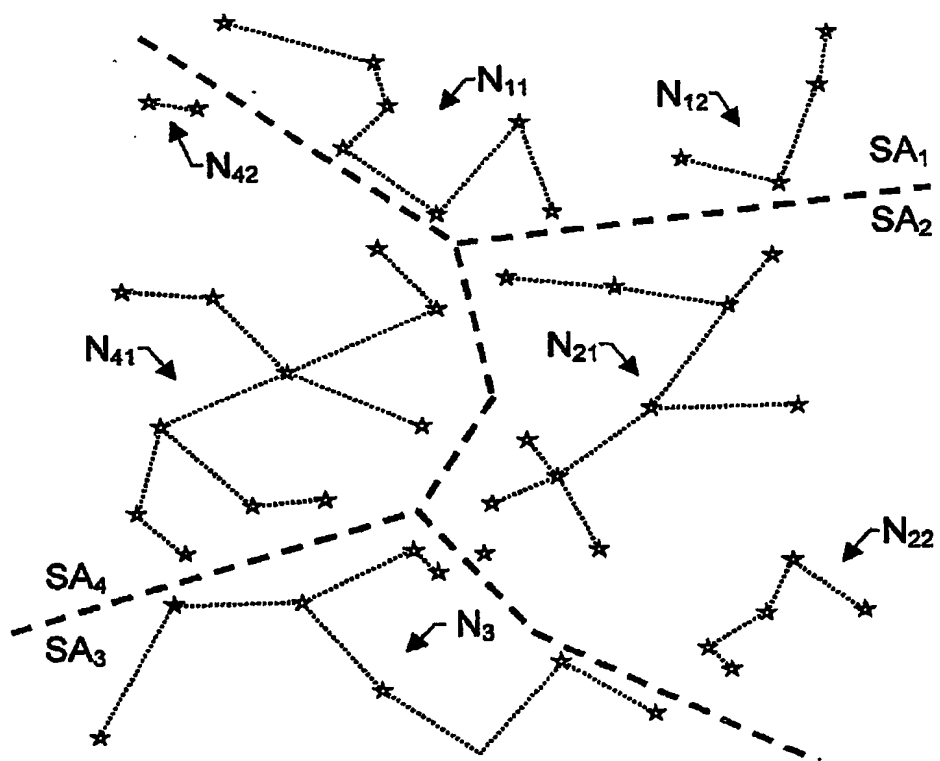


Fig. 4a



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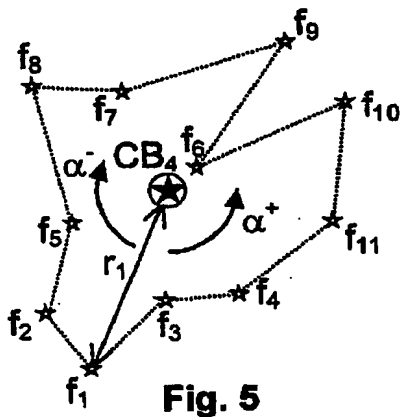


Fig. 5

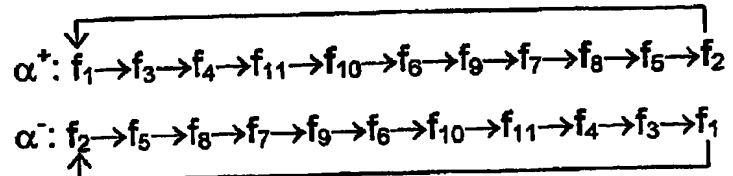


Fig. 6a

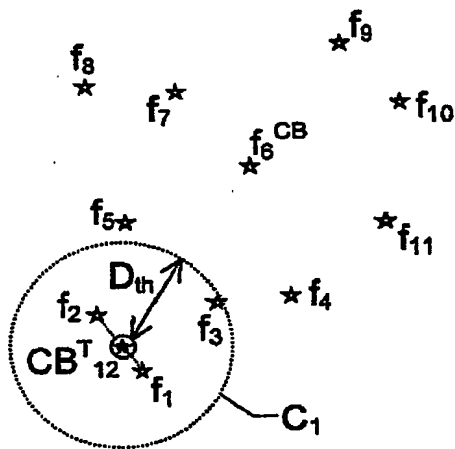
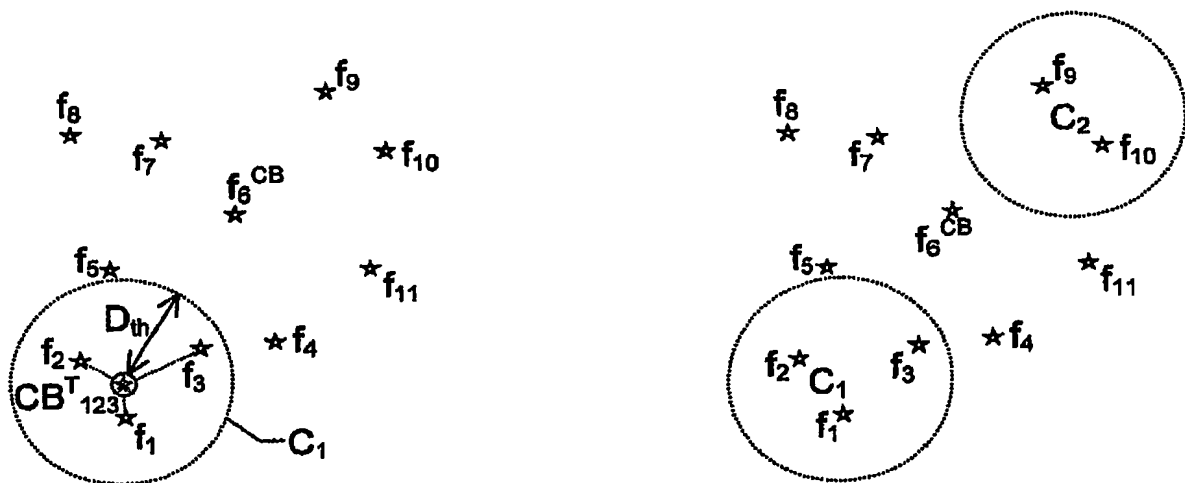


Fig. 7a

610

$\alpha^-$	$f_i(r)$	$\alpha^+$	$C_j$
$f_{10}$	$f_6^{CB}$	$f_9$	$C_5$
$f_8$	$f_5$	$f_2$	$C_5$
$f_9$	$f_7$	$f_8$	$C_3$
$f_1$	$f_3$	$f_4$	$C_1$
$f_3$	$f_4$	$f_{11}$	$C_4$
$f_4$	$f_{11}$	$f_{10}$	$C_4$
$f_7$	$f_8$	$f_5$	$C_3$
$f_6$	$f_9$	$f_7$	$C_2$
$f_5$	$f_2$	$f_1$	$C_1$
$f_{11}$	$f_{10}$	$f_6$	$C_2$
$f_2$	$f_1$	$f_3$	$C_1$

Fig. 6b



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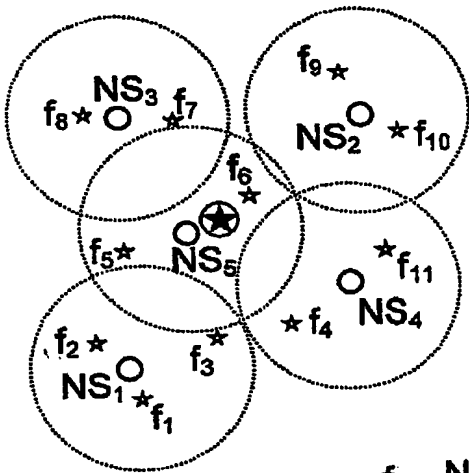


Fig. 8a

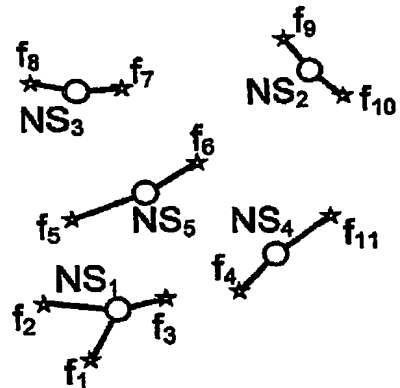


Fig. 8b

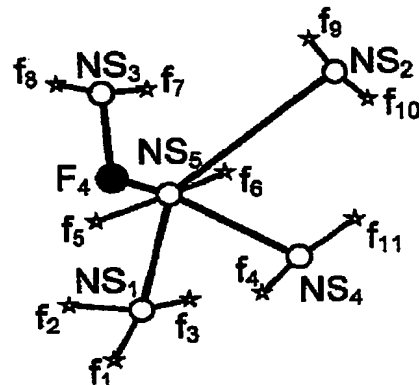


Fig. 8c

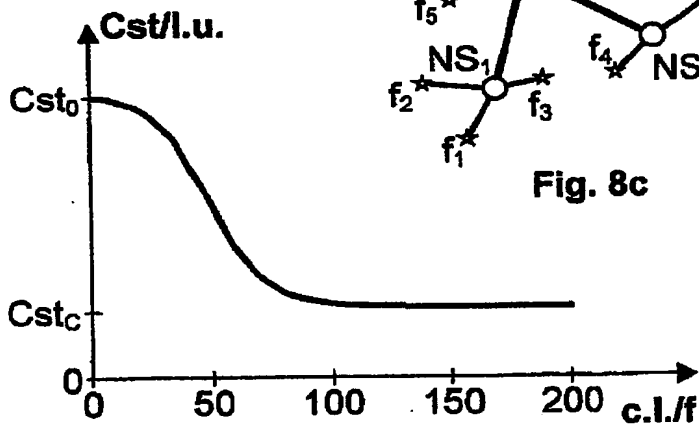
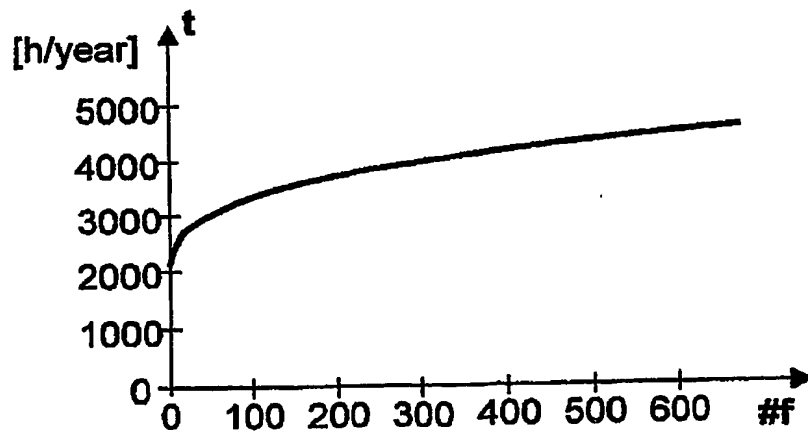


Fig. 11



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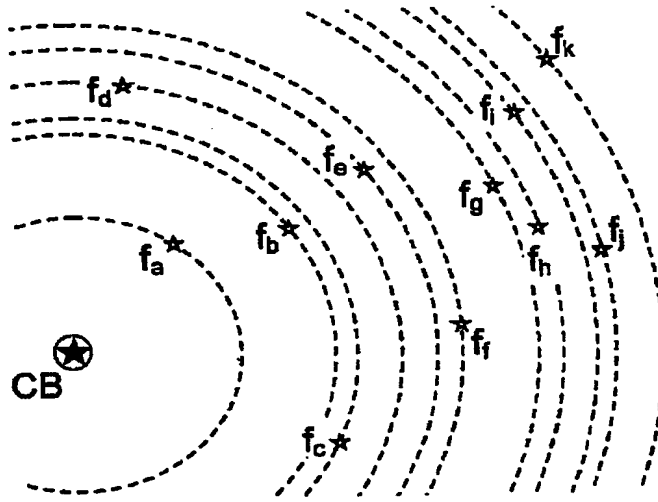


Fig. 9a

910

$\alpha^-$	$\alpha^+$	
$f_e$	$f_a$	$f_d$
$f_k$	$f_b$	$f_o$
---	$f_c$	$f_f$
$f_a$	$f_d$	---
$f_b$	$f_o$	$f_a$
$f_c$	$f_f$	$f_j$
$f_h$	$f_g$	$f_i$
$f_j$	$f_h$	$f_g$
$f_g$	$f_i$	$f_k$
$f_f$	$f_j$	$f_h$
$f_i$	$f_k$	$f_b$

Fig. 9c

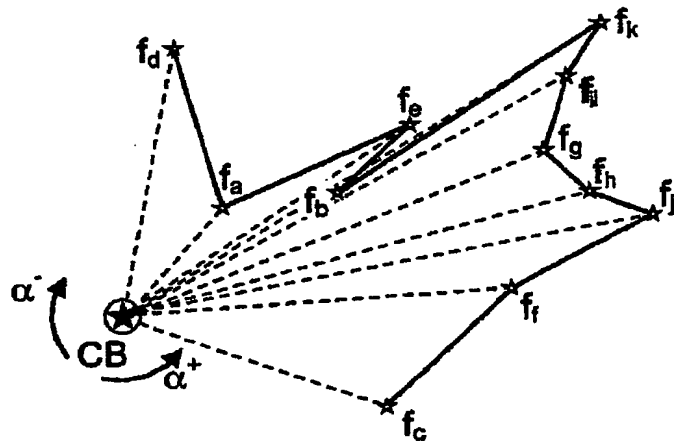


Fig. 9b

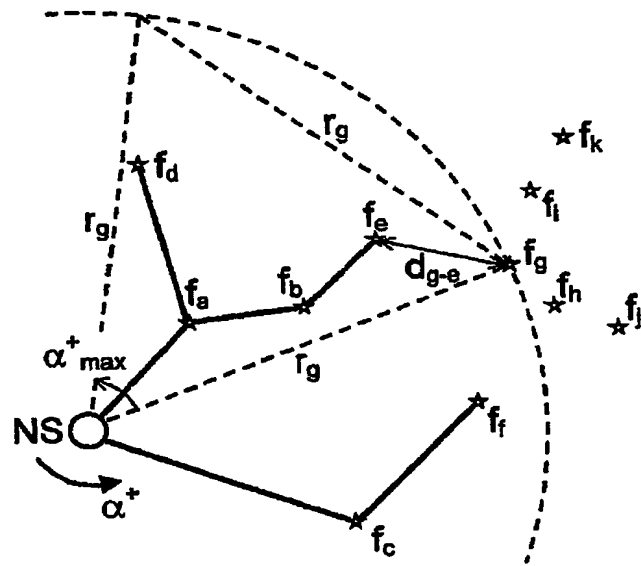


Fig. 10a

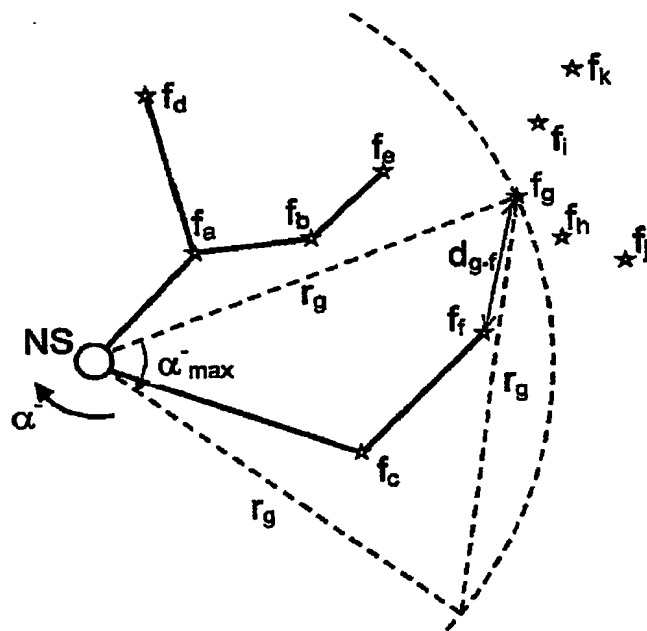


Fig. 10b

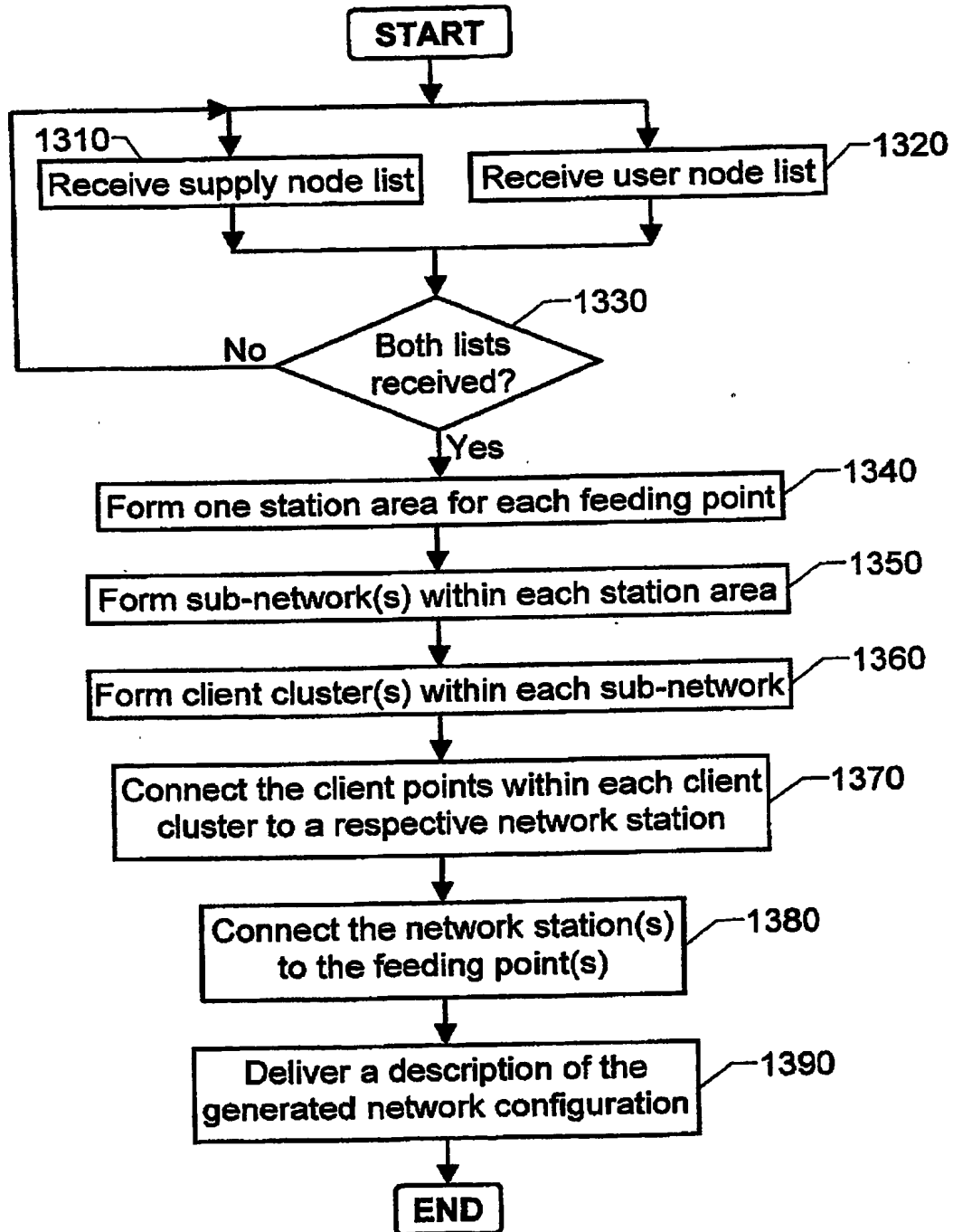


Fig. 13

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